Arnold & Hadley

Effectiveness of
Indirect Illumination

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EFFECTIVENESS OF INDIRECT ILLUMINATION

BY

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HOMER LANGDON HADLEY

THESIS FOR THE DEGREE OF BACHELOR OF SCIENCE

IN ELECTRICAL ENGINEERING, R. H. ARNOLD
IN RAILWAY ELECTRICAL ENGINEERING, H. L. HADLEY

IN THE

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OF THE

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UNIVERSITY OF ILLINOIS

June 1, 1909

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

ROSS HARPER ARNOLD

ENTITLED EFFECTIVENESS OF INDIRECT ILLUMINATION

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Electrical Engineering

T. H. Amrine
Instructor in Charge

APPROVED: Morgan Brooks.

HEAD OF DEPARTMENT OF Electrical Engineering

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APPROVED: Edward C. Schmidt

HEAD OF DEPARTMENT OF Railway Engineering

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INTRODUCTION

As various improvements are being made in the different sources of illumination, the distribution of light to the best advantage has become more and more important. The subject is an old one from the standpoint of the physicist but a comparatively new one to the engineer. The demand for improved sources of light has been complied with to a certain extent and for the past few years the attention of the engineer has been turned to the distribution of this light to render it as effective as possible with the highest efficiency. This involves the use of shades of various shapes and a knowledge of the principles of the reflection of light. Much progress has been made in the past few years in methods of light distribution by means of variously shaped reflectors, but today attention is being attracted to the remarkably uniform distribution and pleasing effect to the eye accomplished by the reflection of the light from the ceiling.

DESCRIPTION of LAMP

The lighting arrangement consists of a tungsten lamp inserted in a bowl shaped, corrugated, silvered glass marror reflector which rests in a suitable metal receptacle, the whole being suspended from the ceiling as shown in the print. The lamp is invisible to persons in the room and the light is directed upward by the reflector to the ceiling and the upper walls and thence to the lower part of the room by diffuse reflection. The reflector is designed with a bowl shape that produces a large

flux of light at the center of the ceiling, the intensity decreasing toward the side walls. Thus it is that a higher efficiency in illumination is obtained, for by directing much of the light to the central part of the ceiling, it is reflected down to the useful plane with only two reflections, causing a minimum loss and thereby overcoming one element of inefficiency present in many lighting systems where the light is reflected back and forth many times from wall to wall.

This type of reflector consists of one piece of glass with a mirror coating of quicksilver applied to the outside which in turn is protected by a coating of paint or enamel which does not crack with the changes in temperature. The reflector is corrugated to eliminate the streaks upon the ceiling that are so often seen when the plain reflector or the tungsten lamp alone is used. The reflector is supported by a thin ornamental bowl, similar in shape, suspended from the ceiling.

DESCRIPTION of ILLUMINOMETER

The instrument used in these tests is a portable photometer capable of measuring illumination in candle-feet and if the distance between the plate and the source of light is known, its candle power is easily determined. The design is such that the instrument can be used equally well for almost any photometric work and, while portable and simple, it meets all theoretical requirements with much precision and accuracy within the range of .004 to 2000. foot-candles. As a photometer it possesses all the important features which go to characterize it as being an

an ideal instrument. It has a very sensitive photometric device a reliable comparison light source, a good means for varying the intensity and the operation is simple. The sensitive photometric device is a modified form of the Lummer-Brodhun arrangement. A seasoned incandescent lamp is the comparison light source and its intensity upon the screen is varied by moving the lamp. There are absorption glasses that are used to regulate the intensity upon the screen when the difference between the two lights is too great. A view of the instrument is shown on a following page. The comparison lamp is mounted within a circular metal housing and is carried on a platform arranged to slide in a track lengthwise of the box, the movement being effected through inelastic cords passing around pulleys, one of which is turned by an external hub. The variable distance method of varying the intensity indicates its dependence upon the applicability of the law of the inverse squares for its readings in candle-feet illumination. The light from the comparison lamp falls on the center of a milk glass plate in the compartment at the end of the box. The scale from which the indications of the photometer are read is set in a longitudinal opening in the side of the box, just above the track upon which the lamp moves. This scale consists of an opaque glass having the scale printed upon it. It is covered with a long shutter in order to prevent the exterior light having access to the interior of the box, but the shutter may be raised so as to illuminate the scale when readings are taken.

The elbow at the end of the box may be turned about a horizontal axis and set at any desired angle and hence furnishes a simple means of measureing illumination or light from any direction. In the elbow of the tube is fixed a mirror plate, while at its outer end, free from any obstruction to light, is fixed a translucent glass or test plate, it being found that the test plate of translucent glass ground on its upper surface so that its power of regular reflection is destroyed, is well adapted to the purpose. It also has the property of a well diffusing surface so that its illumination varies very nearly with the angle of incidence of the light. The scale is direct reading, either in foot-candles or in candle-power. The range is from 0.40 to 20. but this is increased one hundred times by the use of absorbing screens. Two screens may be used, one transmitting ten per cent, the other only one per cent of the light that falls upon it. Either screen may be interposed between the comparison lamp and the prism, or between the prism and the elbow when a greater range than that of the scale is required. Thus when the screens are used, the total range of measurment is from .004 to 2000 foot-candles.

In measuring the candle power a diffusely reflecting surface is turned toward the inside of the tube at the elbow and the end of the elbow tube is left open, the tube serving to screen off stray light from the plate. The distance between the plate and the source of light must be known. The method of calibrating the instrument for the measurment of candle power or

illumunation is that of employing a known candle power or illumination produced by a standard lamp. The voltage of the comparison lamp is adjusted by means of a slide rheostat on the box to such a value that the pointer over the scale indicates the candle power or candle-feet illumination. The instrument thus furnishes a means of reading values directly. The comparison lamp in the photometer is operated from the same circuit as supplies the lighting of the room, thus minimizing the effect of variations in the voltage. The voltage, however, should not vary more than a few volts from the normal, as otherwise an appreciable error will be introduced.

DESCRIPTION of ROOM

In as much as results obtained may be affected somewhat by existing conditions of the room in which the tests were made it is only fair that these conditions be noted before conclusions are drawn.

The room is 15 x 17 feet with two windows as shown on page 9 . The ceiling was of ordinary plaster, whitewashed, but having no perceptible glaze. The walls were a light yellowish color, glazed to reflect as much of the light as possible. Dark green curtains, covering from 80 to 90 per cent of the wall surface, were provided, that the lighting effect might be changed. Curtains of a light orange color also constituted part of the wall equipement, but the results of several tests showed that there was little difference between the coefficients of

absorption, hence the green curtains only were used. The floor had a dark finish. In one corner of the room there was a large roll top desk, the reflection from which somewhat affected the distribution of light in that part of the room.

METHOD

The tests made consist of measuring the illumination of the room in candle-feet with the instrument already described. (one candle-foot is the illumination given at a distance of one foot by a lamp of one candle power. With a known distance and a given candle power, the candle-feet illumination is found by dividing the candle power by the square of the distance in feet.)

The lamp being hung in the center of the room, readings in candle-feet were taken at the points of the room, A1, A2, etc, as shown on the diagram, page 9 . The illuminometer was set at a height of about three feet from the floor so as to read the illumination at the height of the ordinary reading table.

The object of this thesis being to ascertain the effect of indirect illumination as compared with some of the direct systems in common use today, it was necessary to measure the illuminating power of the direct as well as the indirect systems in order that comparisons between them might be made and definite conclusions drawn. With this in view, tests were made with the direct systems using the ordinary lamps arranged with suitable reflectors for good distribution of the light. In all tests an attempt was made to get the same character of distribution as

that given by the indirect system. The tests may be classified under the three following heads:

(1) Direct system having same candle power as the indirect.

(2) " " giving " illumination " " " .

(3) " " using " power " " " .

A number of preliminary readings were taken in every case to ascertain the arrangement of lamps to give the desired illumination and distribution resembling that of the indirect system. In general the following arrangements of lamps were used in the various tests;

(a) Lamps distributed symetrically about the ceiling.

(b) " in cluster at center of room.

(c) Combination of (a) and (b).

The single lamps were suspended 12" from the ceiling, that giving the most uniform lighting for the room with the shades used. Each lamp had a 12" Holophane reflector as shown in cut on a following page. Those in cluster were suspended 18" below the center of the ceiling and had a white porcelain reflector over all with a small Holophane reflector over the lower light as shown in cut. In all cases two sets of readings were taken, one with the bare walls and the other with the green curtains down and each reading given herewith is the mean of two. As the data in this form cannot be comprehended very readily and moreover does not furnish a very accurate and definite means for

comparing the results. Curves are submitted to accompany each set of data. These curves consist simply of lines drawn thru' points of the room having equal illumination, being similar to those of any contour map. The unit of contour interval in this case being the candle-foot.

DIAGRAM of FLOOR.

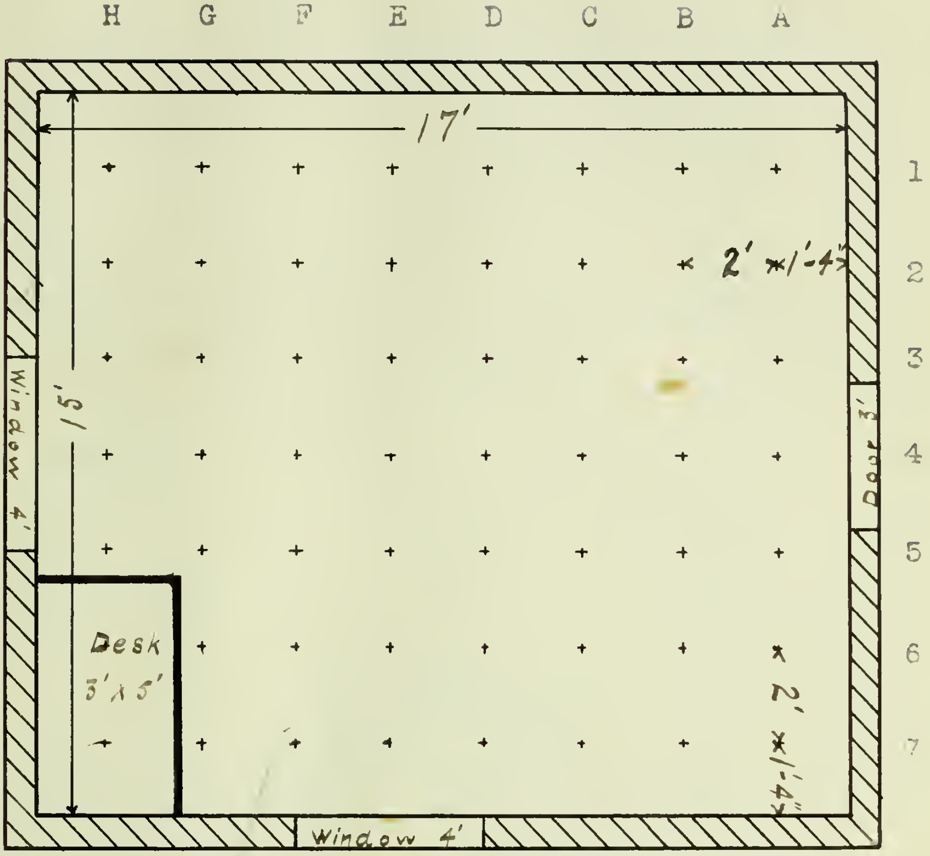


Diagram of floor showing position of illuminometer for readings.

DIAGRAM of CEILING.

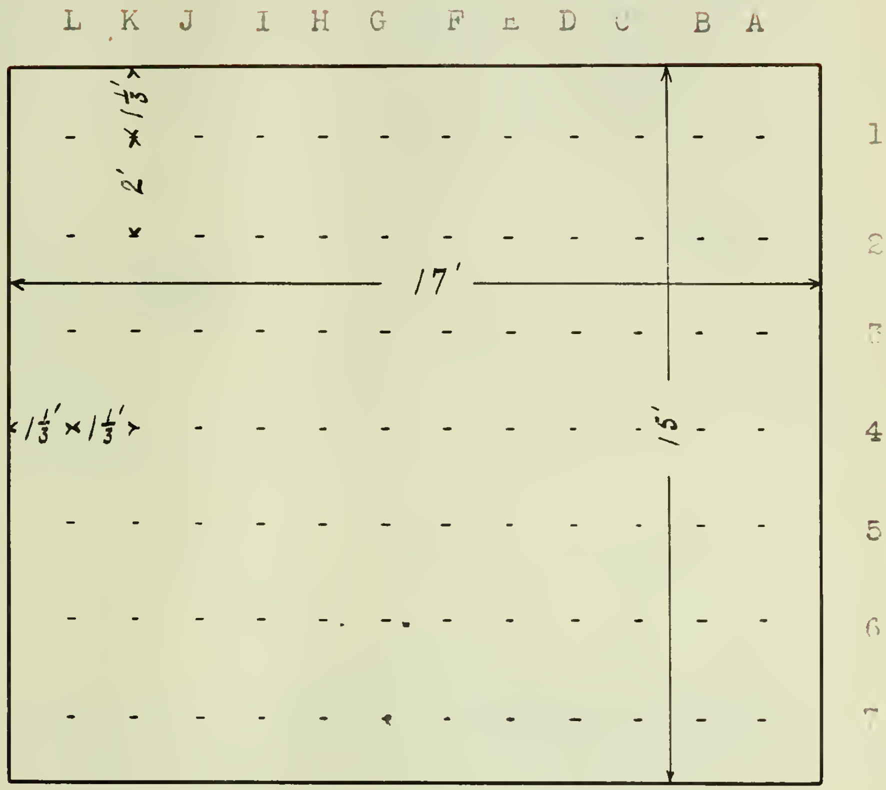
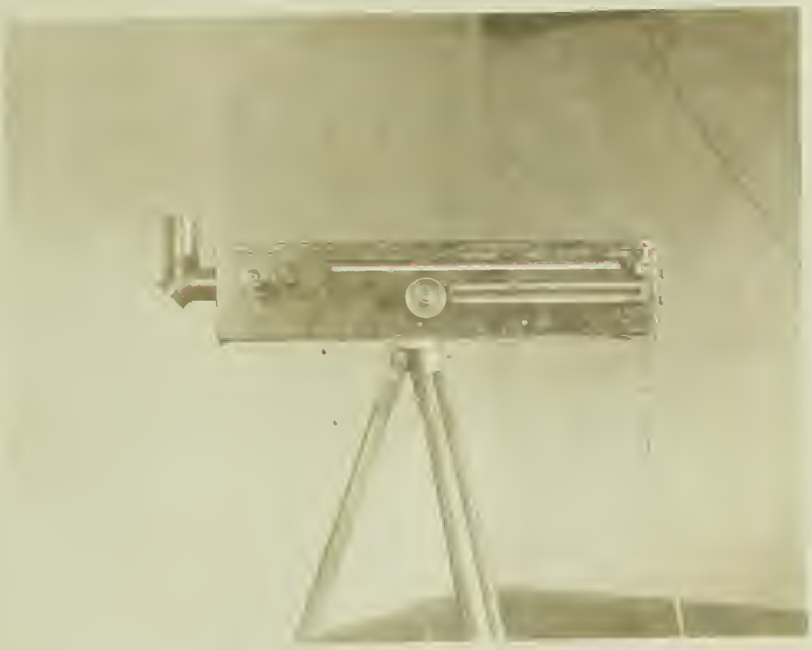


Diagram of ceiling showing positions of lamps for reference.

Lamp used in Indirect System.

Cluster

Holophane shade.



Illuminometer.

DISCUSSION

INDIRECT SYSTEM , NORMAL HEIGHT.

The lamp being hung in the center of the room at its normal height (27" from the ceiling) , readings in foot-candles were taken at the points A1, B3, etc. as shown on page 10. The readings are herewith given on page 16 and the curves for the same are shown on the following pages. These show that the illumination with the walls bare varied quite uniformly from 2.50 at the center to 0.60 candle-feet at the edge of the room. The green curtains lowered the illumination about 15% at the center and 20% at the edges, showing the curtains to have a greater effect at the edges than at the center of the room, as was to be expected.

INDIRECT SYSTEM, VARYING HEIGHTS.

In order that some idea may be obtained in regard to the conditions under which the indirect system might prove to be the more efficient, the distance of the inverted lamp from the ceiling was varied.

Being first hung 20" from the ceiling readings were taken as before as given on page 19 , the curves following. Under these conditions the illumination varied quite uniformly from 0.54 to 2.6 foot-candles from edges to the center of the room respectively.

In a second trial with the lamp 36" below the ceiling, there was a marked decrease in the illumination over that in the test just mentioned, the readings varying from 0.54 at the edges to

2.0 candle-feet at the center of the room. Data on page 22 with the curves following indicate that with the lamp in the lower position more of the direct light rays from the lamp struck the upper part of the walls which had a greater coefficient of absorption than the ceiling and hence the useful illumination was less.

DIRECT SYSTEM. SAME CANDLE POWER AS INDIRECT SYSTEM.

In the direct system, the final arrangement consisted in distributing four sixteen and one eight candle power lamps symetrically about the room, the candle power having been measured and found equal to that of the tungsten lamp used in the indirect system. The eight candle power lamp was placed in the center while the remaining sixteen candle power lamps were placed towards the corners of the room, thus giving a symetrical distribution of light, and by shifting the lamps to and from the corners, the points were found at which the distribution was similar to that of the indirect system. The data and curves, pages 25 to 27 , shows a variation of from 0.80 to 2.75 foot-candles with the walls bare and with the green walls the illumination was decreased about thirty-three and eight per cent around the edges and at the center respectively.

DIRECT SYSTEM, SAME ILLUMINATION AS INDIRECT SYSTEM.

This test of the direct system consisted of two arrangements, selected only after several trials, the object being to get the same intensity of illumination as in the direct system. Even then the illumination was only approximate to that of the indirect, but the results are considered close enough to give a definite idea as to the comparison between them. The first arrangement consisted of four sixteen candle power lamps, the total candle power of which was found by measurement to be 67.6 using 267 watts energy. Each lamp was placed towards the corner of the room at such a distance from the center as to give as uniform a distribution as that of the indirect system. The results are given on page 28 with the curves following. The range was from 0.55 to 1.85 foot -candles, the green walls causing the usual decrease of about ten per cent quite uniformly over the room.

The second arrangement consisted of seven eight and one sixteen candle power lamps, the total candle power being 71.2 . Four of the eight candle power lamps were placed towards the corners of the room, while the remaining lamps were placed in the center in a cluster, the sixteen candle power being in the bottom. Page 31 gives the illumination readings with the curves following. The illumination varied from 0.55 to 2.35 foot-candles, the green walls giving the usual variation of five to fifteen per cent. The power used was 351 watts, being greater than that in the first case because of the smaller and less

efficient size lamps used. The illumination in the latter case was a trifle higher at the center of the room, though that at the edges was practically the same.

DIRECT SYSTEM, SAME POWER AS INDIRECT SYSTEM.

In this test four four candle power lamps were used having a total of 18 candle power and taking 119 watts. Larger and fewer lamps might have been used but then the desired distribution could not have been obtained, though the illumination would have been greater for the same power consumed. The tungsten lamp required 104 watts, which is lower than that used in this arrangement. However by keeping these facts in mind, a fairly definite idea as to the respective systems may be obtained in comparing the illumination of each. As before, the lamps were placed between the center and corners of the room for symetrical and uniform distribution of light. As shown by results on pages 34 to 36 , the illumination was so low that no readings could be obtained at the edges of the room without changing the screens in the illuminometer and as the illumination was too low for any practical use, this was not done. The central readings went only as high as 0.56 candle-feet.

INDIRECT SYSTEM--NORMAL HEIGHT.

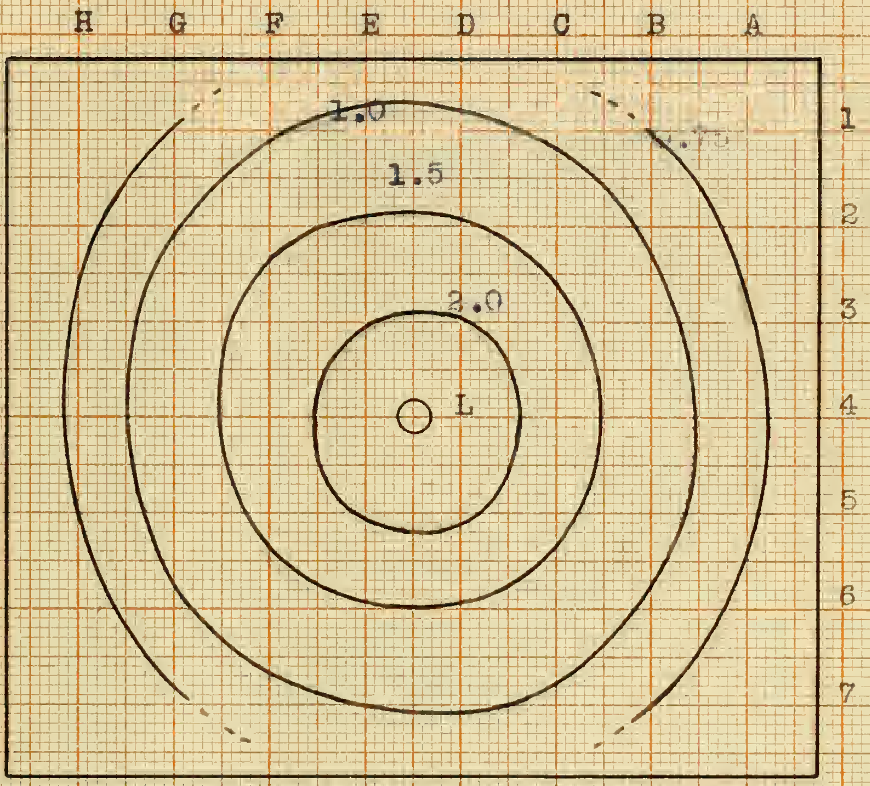
Edge of bowl 27 inches below ceiling ---- BARE WALLS--- -

No.	A	B	C	D	E	F	G	H
1	0.53	0.71	0.93	1.11	1.03	0.96	0.76	0.57
2	0.69	0.93	1.24	1.52	1.49	1.4[illegible]	0.97	0.66
3	0.75	1.11	1.63	2.04	1.92	1.73	1.21	0.75
4	0.76	1.25	1.89	2.26	2.25	1.87	1.21	0.75
5	0.80	1.13	1.74	2.10	1.95	1.73	1.13	0.74
6	0.68	0.95	1.34	1.49	1.44	1.31	0.92	0.92
7	0.57	0.72	0.98	1.02	0.97	0.92	0.69	desk

----GREEN WALLS----

No.	A	B	C	D	E	F	G	H
1	0.40	0.53	0.70	0.80	0.89	0.76	0.55	0.40
2	0.48	0.70	0.98	1.30	1.24	1.06	0.77	0.49
3	0.57	0.98	1.32	1.72	1.63	1.38	0.97	0.62
4	0.61	1.08	1.46	1.90	1.88	1.55	1.04	0.63
5	0.59	0.97	1.36	1.72	1.78	1.49	0.93	0.58
6	0.48	0.75	1.07	1.33	1.28	1.04	0.70	0.50
7	0.40	0.52	0.70	0.80	0.83	0.73	0.51	desk

INDIRECT ILLUMINATION.



TUNGSTEN Lamp (L) inverted

at

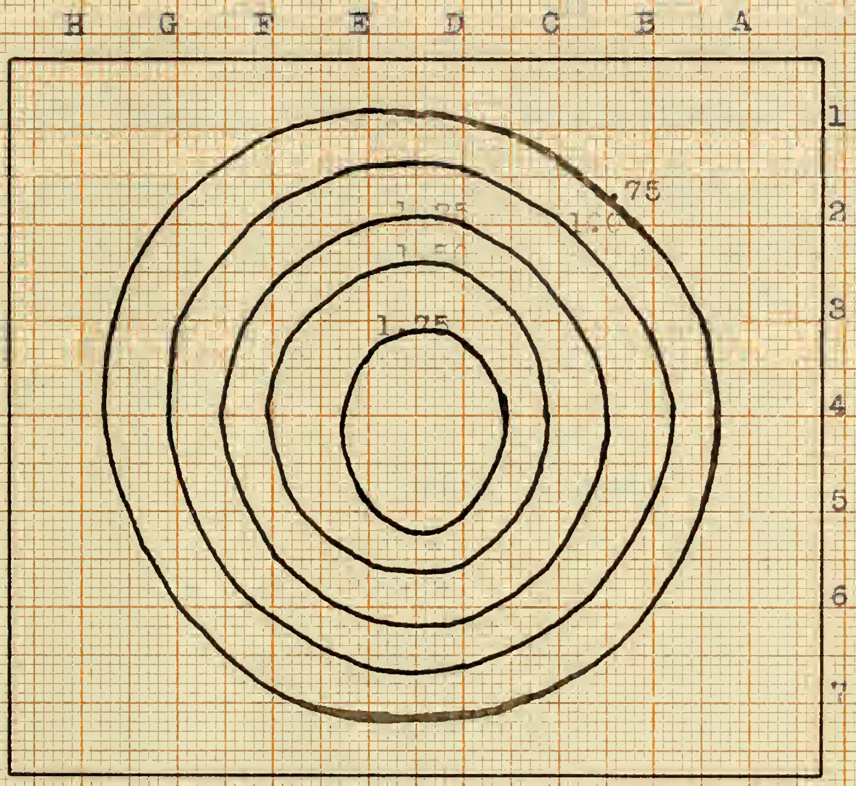
center 27" from ceiling.

Candle power----------83.2

Watts (Power used)--104.0

Light walls.

INDIRECT ILLUMINATION.



TUNGSTEN Lamp (L) inverted.

at

center 27" from ceiling .

Candle power ----------83.2

Watts (Power used)---104.0

Green walls.

INDIRECT SYSTEM--VARYING HEIGHT.

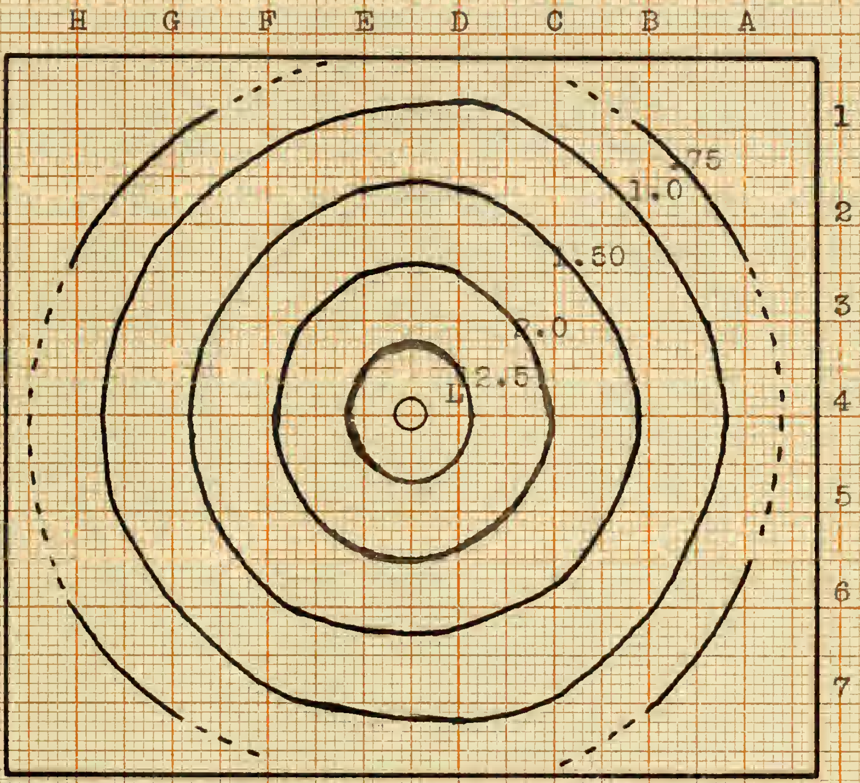
20" below ceiling. ----BARE WALLS------

No.	A	B	C	D	E	F	G	H
1	0.55	0.75	0.94	1.14	1.12	0.90	0.74	0.54
2	0.72	1.00	1.36	1.70	1.72	1.32	0.98	0.68
3	0.81	1.26	1.86	2.27	2.28	1.80	1.24	0.80
4	0.85	1.40	2.00	2.60	2.58	1.94	1.37	0.83
5	0.82	1.25	1.82	2.25	2.30	1.80	1.24	0.78
6	0.70	0.98	1.40	1.66	1.63	1.42	0.96	----
7	0.56	0.77	1.00	1.08	1.06	0.93	0.72	----

---GREEN WALLS------

1	0.42	0.60	0.85	1.11	1.09	0.87	0.64	0.40
2	0.55	0.85	1.28	1.68	1.68	1.28	0.87	0.54
3	0.70	1.12	1.83	2.30	2.30	1.75	1.15	0.68
4	0.70	1.22	2.00	2.59	2.60	1.98	1.30	0.73
5	0.68	1.10	1.78	2.27	2.34	1.75	1.15	0.70
6	0.54	0.84	1.28	1.68	1.65	1.26	0.83	----
7	0.43	0.56	0.90	1.00	0.99	0.85	0.55	----

INDIRECT ILLUMINATION.



TUNGSTEN Lamp (L) inverted

at

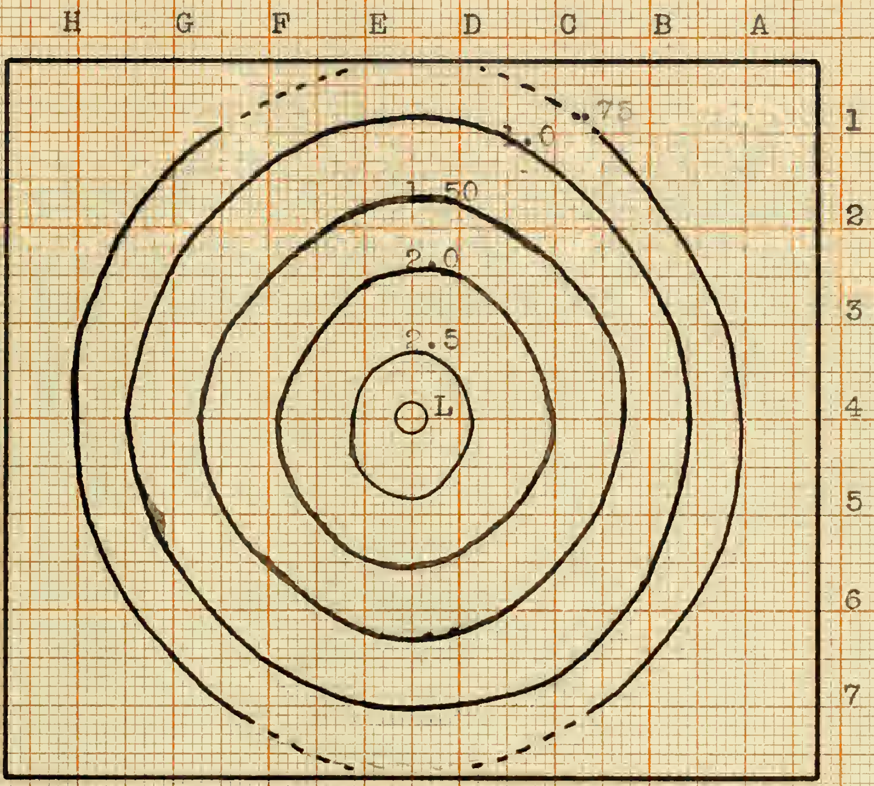
center 20" from ceiling.

Candle power ---------83.2

Power used (Watts)--104.0

Light walls.

INDIERCT ILLUMINATION.



TUNGSTEN Lamp (L) inverted

at

Center 20" from ceiling.

Candle power --------83.2

Power used(Watts)---104.0

Green walls.

INDIRECT SYSTEM--VARYING HEIGHT.

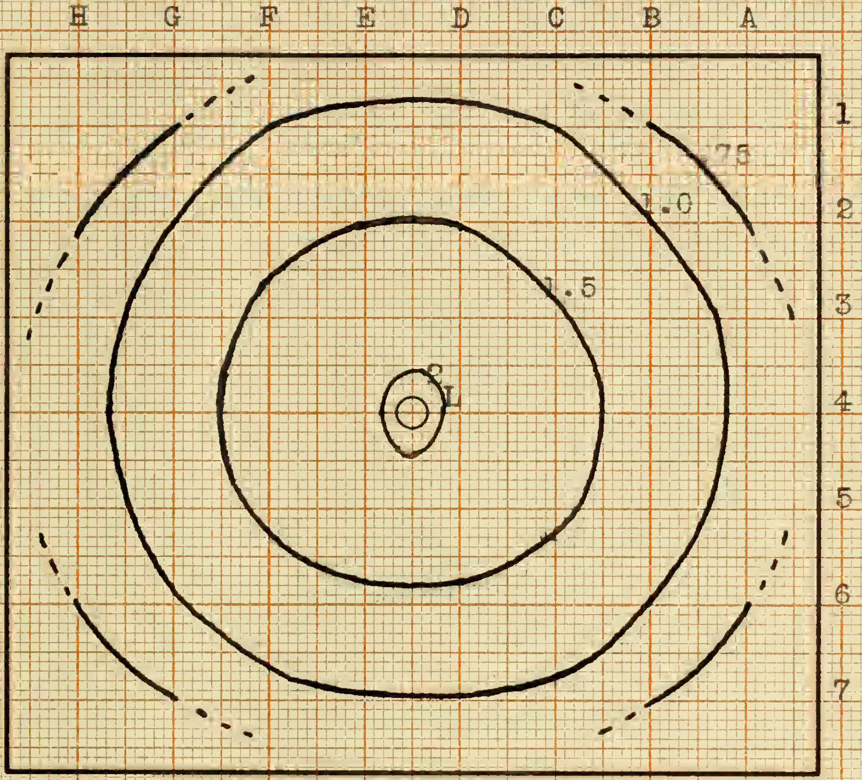
36" below ceiling. -----BARE WALLS--

No.	A	B	C	D	E	F	G	H
1	0.60	0.75	1.00	1.05	1.06	1.00	0.75	0.62
2	0.74	1.00	1.26	1.45	1.50	1.28	1.00	0.74
3	0.89	1.20	1.62	1.83	1.85	1.64	1.22	0.80
4	0.90	1.32	1.68	1.98	1.95	1.65	1.35	0.78
5	0.90	1.18	1.56	1.80	1.82	1.58	1.23	0.78
6	0.76	0.98	1.26	1.37	1.45	1.25	0.96	0.75
7	0.58	0.76	0.95	0.98	1.00	0.94	0.75	----

-----GREEN WALLS

No.	A	B	C	D	E	F	G	H
1	0.44	0.66	0.85	1.02	1.01	0.90	0.70	0.46
2	0.59	0.88	1.25	1.47	1.45	1.25	0.91	0.62
3	0.70	1.10	1.60	1.92	1.85	1.56	1.12	0.70
4	0.75	1.20	1.78	2.08	2.05	1.65	1.20	0.75
5	0.72	1.10	1.60	1.82	1.90	1.54	1.08	0.72
6	0.58	0.87	1.20	1.42	1.40	1.19	0.88	0.75
7	0.45	0.65	0.90	0.93	0.90	0.81	0.62	----

INDIRECT ILLUMINATION.



TUNGSTEN Lamp (L) inverted

at

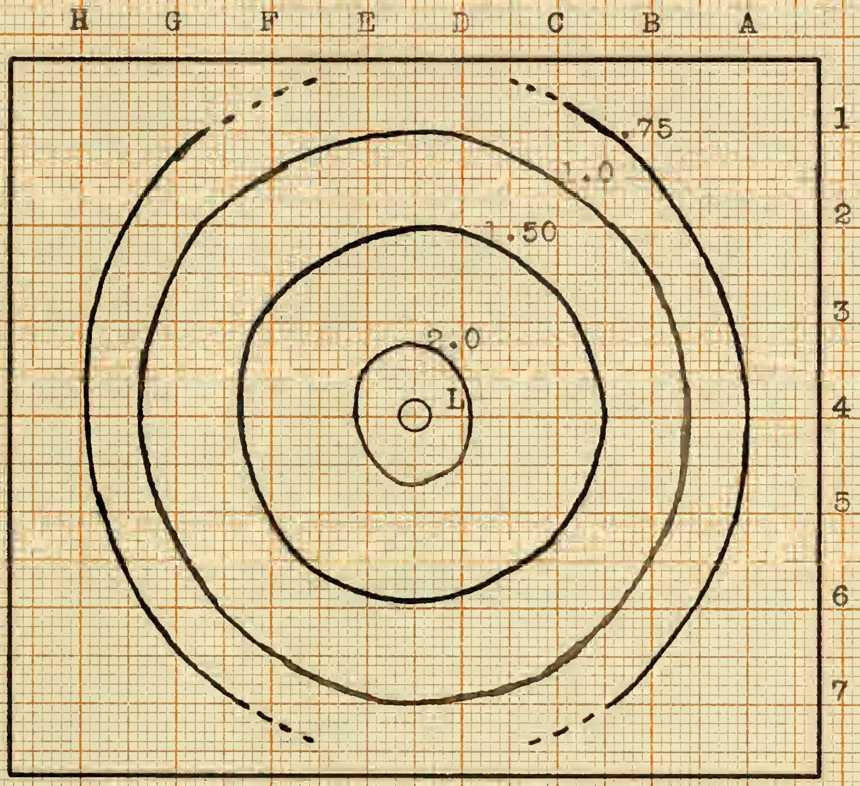
center 36" from ceiling.

Candle power ---------83.2

Power used (Watts)---104.0

Light walls.

INDIRECT ILLUMIATION.



TUNGSTEN Lamp (L) inverted

at

center 36" from ceiling.

Candle power ---------83.2

Power used (Watts)---104.0

Green walls.

DIRECT SYSTEM--EQUAL CANDLE POWER

Four 16 c.p. and one 8 c.p. lamps, total of 83 candle power.

Holophane shades over lamps.

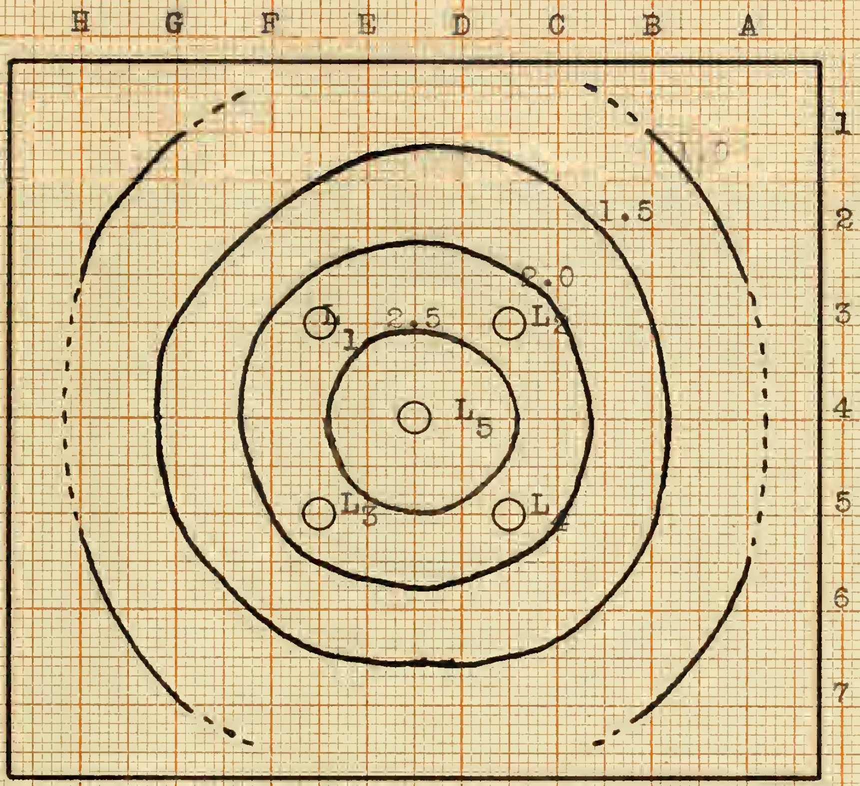
-----BARE WALLS---

No.	A	B	C	D	E	F	G	H
1	0.79	1.01	1.24	1.37	1.37	1.16	1.00	0.80
2	0.88	1.18	1.68	1.85	1.82	1.58	1.25	0.94
3	1.10	1.50	2.13	2.40	2.45	2.03	1.48	1.03
4	1.08	1.61	2.24	2.75	2.74	2.20	1.58	1.08
5	1.10	1.52	2.13	2.45	2.46	2.06	1.52	1.04
6	0.94	1.26	1.65	1.80	1.83	1.58	1.27	0.90
7	0.80	1.00	1.20	1.24	1.22	1.18	1.02	----

----GREEN WALLS----

No.	A	B	C	D	E	F	G	H
1	0.54	0.80	1.12	1.13	1.13	1.13	0.78	0.52
2	0.70	1.10	1.50	1.66	1.70	1.49	1.11	0.80
3	0.91	1.38	1.95	2.24	2.25	1.94	1.38	0.90
4	0.93	1.52	2.00	2.54	2.52	2.05	1.50	0.95
5	0.90	1.38	1.92	2.26	2.25	1.90	1.38	0.92
6	0.70	1.15	1.48	1.75	1.73	1.50	1.13	0.85
7	0.53	0.74	0.95	1.10	1.12	1.12	0.75	----

DIRECT ILLUMINATION.

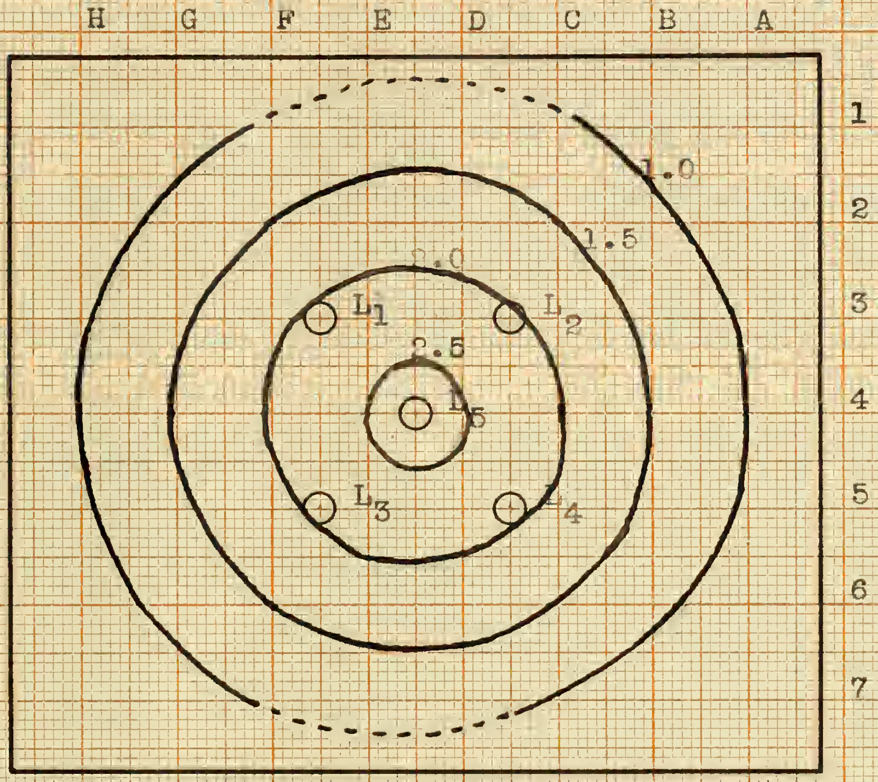


CARBON Lamps.

	Candle power	Power (Watts)
L_1	18.0	67.0
L_2	19.6	70.0
L_3	17.8	70.0
L_4	18.4	67.0
L_5	9.0	42.0
Total	82.8	316.0

Light walls.

DIRECT ILLUMINATION.



CARBON Lamps,

	Candle power	Power (Watts)
L_1	18.0	67.0
L_2	19.6	70.0
L_3	17.8	70.0
L_4	18.4	67.0
L_5	9.0	42.0
Total	82.8	316.0

Green walls.

DIRECT SYSTEM--EQUAL ILLUMINATION.

Four 16 candle power lamps, total of 68 candle power, 267 watts.

Holophane shades over lamps.

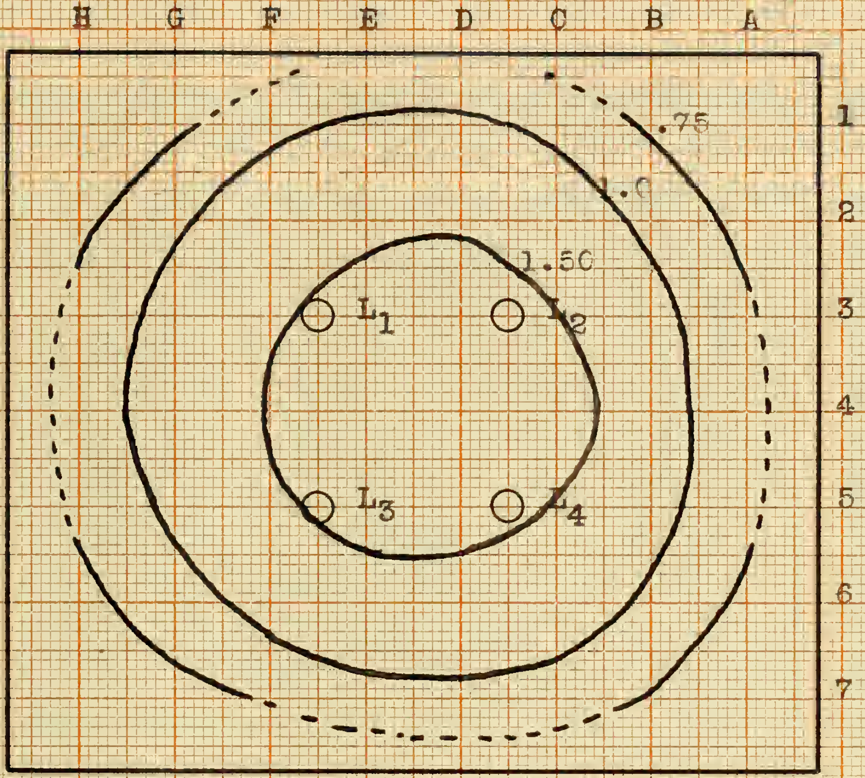
----BARE WALLS-------

No.	A	B	C	D	E	F	G	H
1	0.54	0.72	0.92	1.00	1.10	0.91	0.71	0.61
2	0.70	0.90	1.22	1.45	1.34	1.24	0.92	0.73
3	0.78	1.13	1.53	1.76	1.77	1.42	1.14	0.79
4	0.77	1.22	1.68	1.86	1.82	1.53	1.18	0.81
5	0.78	1.09	1.51	1.71	1.71	1.40	1.11	0.78
6	0.70	0.92	1.26	1.29	1.21	1.12	0.86	0.71
7	0.55	0.74	0.90	0.93	0.85	0.78	0.66	----

---GREEN WALLS------

1	0.40	0.57	0.79	0.87	0.87	0.80	0.54	0.41
2	0.49	0.74	1.17	1.25	1.20	1.03	0.75	0.56
3	0.64	1.00	1.47	1.65	1.53	1.25	1.04	0.67
4	0.68	1.09	1.49	1.75	1.65	1.42	1.07	0.70
5	0.64	0.98	1.46	1.60	1.58	1.28	0.94	0.65
6	0.49	0.76	1.12	1.16	1.14	1.00	0.72	0.60
7	0.40	0.54	0.70	0.81	0.82	0.69	0.5[illegible]	----

DIRECT ILLUMINATION.

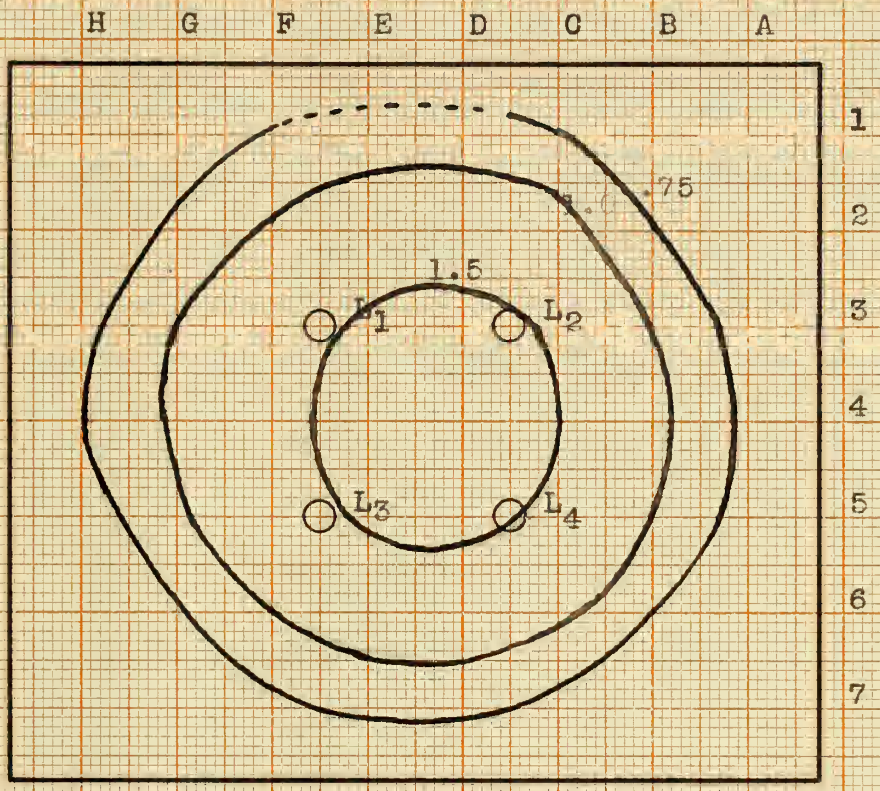


CARBON Lamps.

	Candle power	Power (Watts)
L_1	16.2	67.0
L_2	17.8	70.0
L_3	15.6	63.0
L_4	18.0	67.0
Total	67.0	267.0

Light walls

DIRECT ILLUMINATION.



CARBON Lamps.

	Candle power	Power (Watts)
L_1	16.2	67.0
L_2	17.8	70.0
L_3	15.0	63.0
L_4	18.0	67.0
Total	67.0	267.0

Green walls.

DIRECT SYSTEM--EQUAL ILLUMINATION.

Seven 8 candle power lamps, total of 71 candle power, 356 W.

Holophane shades and white reflector over lamps.

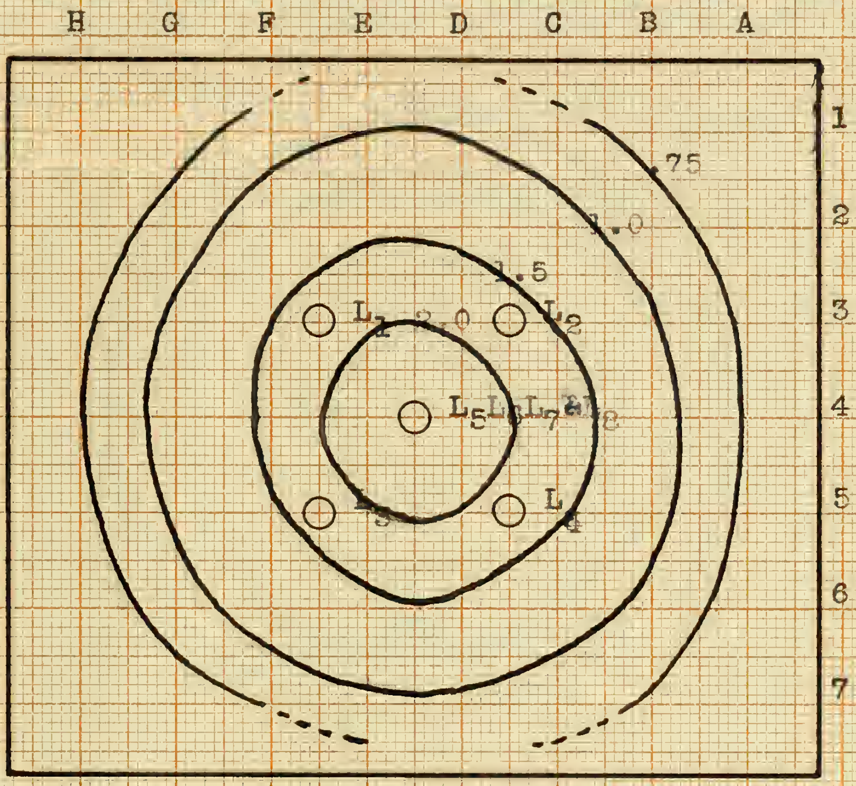
One sixteen candle power lamp. -----BARE WALLS--------

No.	A	B	C	D	E	F	G	H
1	0.54	0.69	0.84	0.97	0.98	0.83	0.67	0.54
2	0.61	0.85	1.12	1.37	1.41	1.20	0.85	0.63
3	0.71	1.11	1.48	1.88	1.97	1.47	1.04	0.69
4	0.71	1.18	1.88	2.30	2.35	1.64	1.17	0.72
5	0.71	1.10	1.58	1.96	2.07	1.48	1.06	0.67
6	0.64	0.75	[illegible]	[illegible]	[illegible]	[illegible]	0.38	0.67
7	[illegible]	0.72	[illegible]	[illegible]	0.86	0.76	0.63	----

----GREEN WALLS------

No.	A	B	C	D	E	F	G	H
1	0.40	0.50	0.72	0.79	0.77	0.72	0.51	0.40
2	0.45	0.74	1.00	1.22	1.29	1.04	0.68	0.48
3	0.60	1.00	1.47	1.77	1.92	1.41	0.90	0.59
4	0.61	1.10	1.76	2.22	2.29	1.59	1.05	0.62
5	0.59	0.98	1.47	1.82	2.06	1.48	0.96	0.59
6	0.47	0.77	0.99	1.23	1.34	1.05	0.78	0.57
7	0.40	0.50	0.63	0.79	0.78	0.66	0.48	----

DIRECT ILLUMINATION.

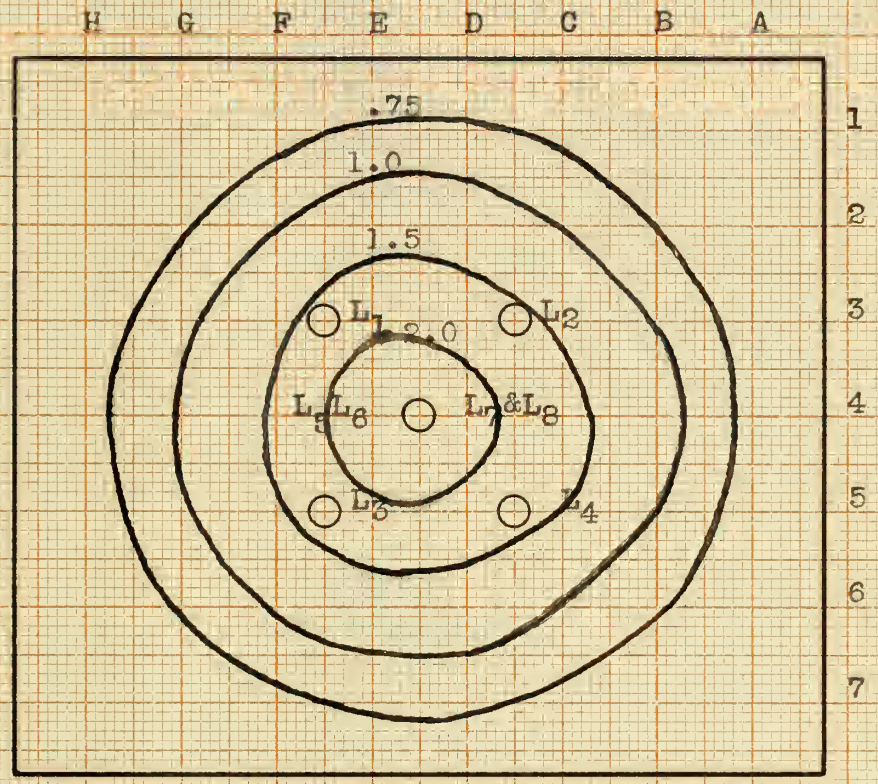


CARBON Lamps.

	Candle power	Power (Watts)
L_1	7.6	40.0
L_2	8.2	41.0
L_3	7.5	40.0
L_4	8.4	42.0
L_5	7.8	40.0
L_6	7.5	40.0
L_7	8.1	41.0
L_8	16.2	67.0
Total	71.3	351.0

Light walls

DIRECT ILLUMINATION.



CARBON Lamps.

	Candle power	Power(Watts).
L_1	7.6	40.0
L_2	8.2	41.0
L_3	7.5	40.0
L_4	; 8.4	42.0
L_5	7.8	40.0
L_6	7.6	40.0
L_7	8.1	41.0
L_8	16.2	67.0
Total	71.3	351.0

Green walls.

DIRECT SYSTEM--EQUAL WATTS.

Four four candle power lamps, total of 18 candle power, 119 watts.

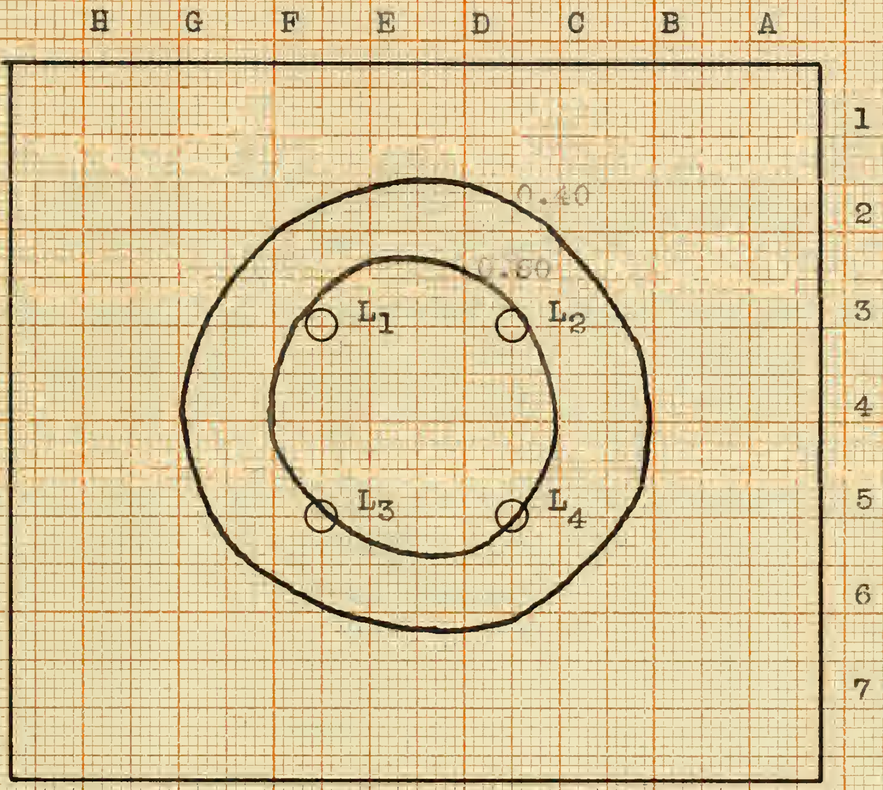
Holophane shades over lamps. -----GREEN WALLS-

No.	A	B	C	D	E	F	G	H
1	----	----	----	----	----	----	----	----
2	----	----	0.38	0.40	0.40	0.38	----	----
3	----	0.33	0.44	0.52	0.52	0.45	0.34	----
4	----	0.36	0.46	0.53	0.53	0.43	0.38	----
5	----	0.34	0.44	0.52	0.51	0.47	0.33	----
6	----	----	0.34	0.38	0.38	0.33	----	----
7	----	----	----	----	----	----	----	----

----BARE WALLS---

No.	A	B	C	D	E	F	G	H
1	----	----	----	----	----	----	----	----
2	----	----	0.39	0.45	0.46	0.40	----	----
3	----	0.35	0.48	0.57	0.58	0.47	0.38	----
4	----	0.39	0.50	0.56	0.56	0.50	0.40	----
5	----	0.36	0.47	0.57	0.53	0.46	0.38	----
6	----	----	0.36	0.43	0.44	0.36	----	----
7	----	----	----	----	----	----	----	----

DIRECT ILLUMINATION.

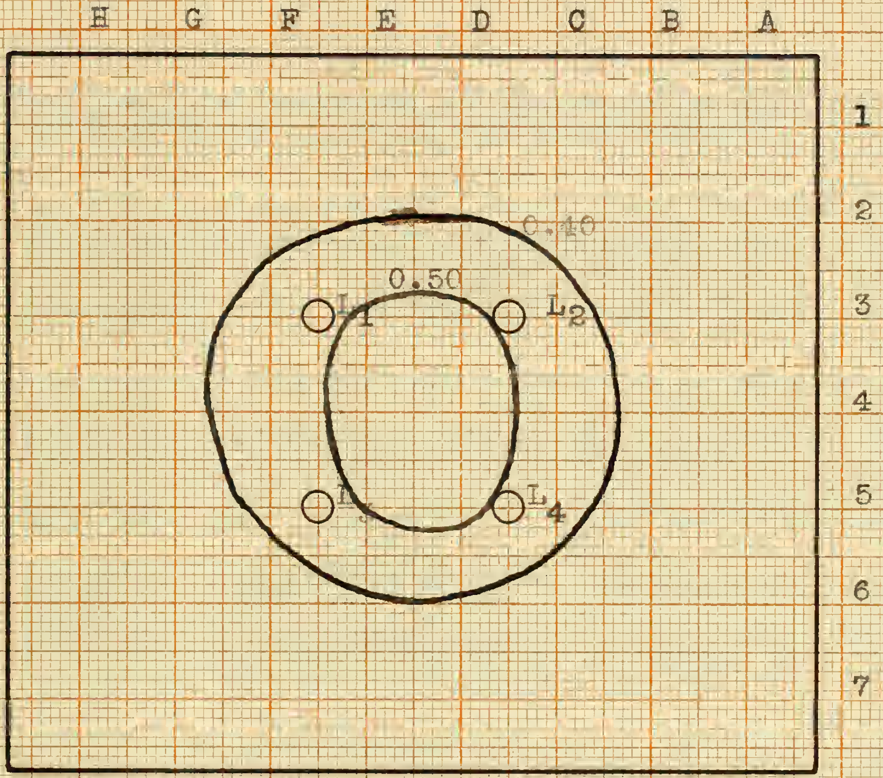


CARBON Lamps.

	Candle power	Power (Watts).
L_1	4.4	30.0
L_2	4.8	30.0
L_3	4.4	30.0
L_4	4.3	30.0
Total	17.9	119.0

Light walls.

DIRECT ILLUMINATION.



CARBON Lamps.

	Candle power	Power (Watts).
L_1	4.4	30.0
L_2	4.8	30.0
L_3	4.4	29.0
L_4	4.3	30.0
Total	17.9	119.0

Green walls.

GENERAL CONCLUSIONS

The results of tests made upon the indirect system of lighting show that a one hundred watt yungsten inverted lamp in the average size living room will give sufficient illumination for ordinary purposes. In the room in which the tests were made the coefficient of absorption of the walls was considerably greater than that of the ceiling and this served to emphasize the fact that the lamp should be hung at such a height that few of the direct rays of light from the lamp should strike the walls. The light striking the upper part of the walls is reflected to the ceiling instead of downward to the reading or useful plane of the room. There was a very marked difference in the illumination with the lamp placed at different heights. At a distance of twenty inches from the ceiling there was an increase of about fifteen per cent in the illumination at the center of the room while at the edges it was practically the same, as compared with that with the lamp in its normal position. This increase is accounted for by the fact that less of the direct light from the lamp struck the walls than did in the normal position and hence more was reflected from the ceiling. The green walls caused a decrease of fifteen to twenty per cent at the edges while at the center there was no decrease whatever as so little of the direct light struck the walls. At the normal height the decrease was quite uniformly sixteen per cent.

At a distance of three feet below the ceiling the illumination at the center of the room was fifteen per cent below normal while

at the edges there was about the same per cent increase, as compared with the normal position. The green walls had no effect at the center but lowered the illumination at the edges by about twenty per cent. This shows that the normal height of the lamp (27" below ceiling) is better suited to a larger room as the light reflected by the ceiling seems to be absorbed by the walls to a greater extent with the lower positions of the lamp, as compared with the twenty inch below ceiling position. The green walls also have a greater effect in decreasing the illumination at the edges of the room as the lamp is lowered.

The carbon lamps in the direct system having the same candle power as the inverted tungsten have a twenty five to thirty per cent higher illuminating power than the tungsten at all points of the room. The green walls do not cause such a noticeable decrease in the illumination because the lamps and their reflectors throw the light directly to the floor.

In all trial tests to determine the arrangement for the same illumination as given by the indirect system, the use of seven eight and one sixteen candle power, or of four sixteen candle power carbon lamps was found to be the most satisfactory. The illumination from the first arrangement was almost the same, though perhaps a trifle low at the edges of the room. The slight decrease in illumination with the green walls, as compared with the same decrease in the indirect system, is again notice-

able. The candle power in this case was fifteen less than in tge indirect system. The power used was 267 watts, as compared with 104 in the indirect system. Since the tungsten indirect uses only 39 per cent the power that the carbon direct system does to give the same illumination, the efficiency of the former is over twice as great as that of the latter.

The efficiency of the indirect tungsten system as compared with the direct carbon is also shown in another way by comparing its illumination with that given by four four candle power carbon lamps using 119 watts. This is fifteen watts more than is required by the inverted tungsten, but the illumination is very much less, being about 75 per cent less at all parts of the room. If this be reduced in terms of 104 watts consumption of power, it would be about 78 per cent less. As these small lamps use about 1.7 the power that the larger lamps do, the illumination would have been about fifty per cent that of the indirect if such larger lamps had been used. With the larger lamps, however, the desired distribution could not be secured.

Thus the results indicate that the indirect system of lighting with the use of the tungsten lamp may be substituted for many of the direct lighting systems of today with the carbon lamps, and the expense of operation will be much decreased. Another great advantage of the indirect system of illumination is the elimination of the discomfort to the eyes of having exposed lamps and also annoying shadows. Lighted in this way, reading

becomes easier, for there is less annoying glare of reflection from the paper and conditions more nearly approach that of daylight.